United States
Department of
Agriculture

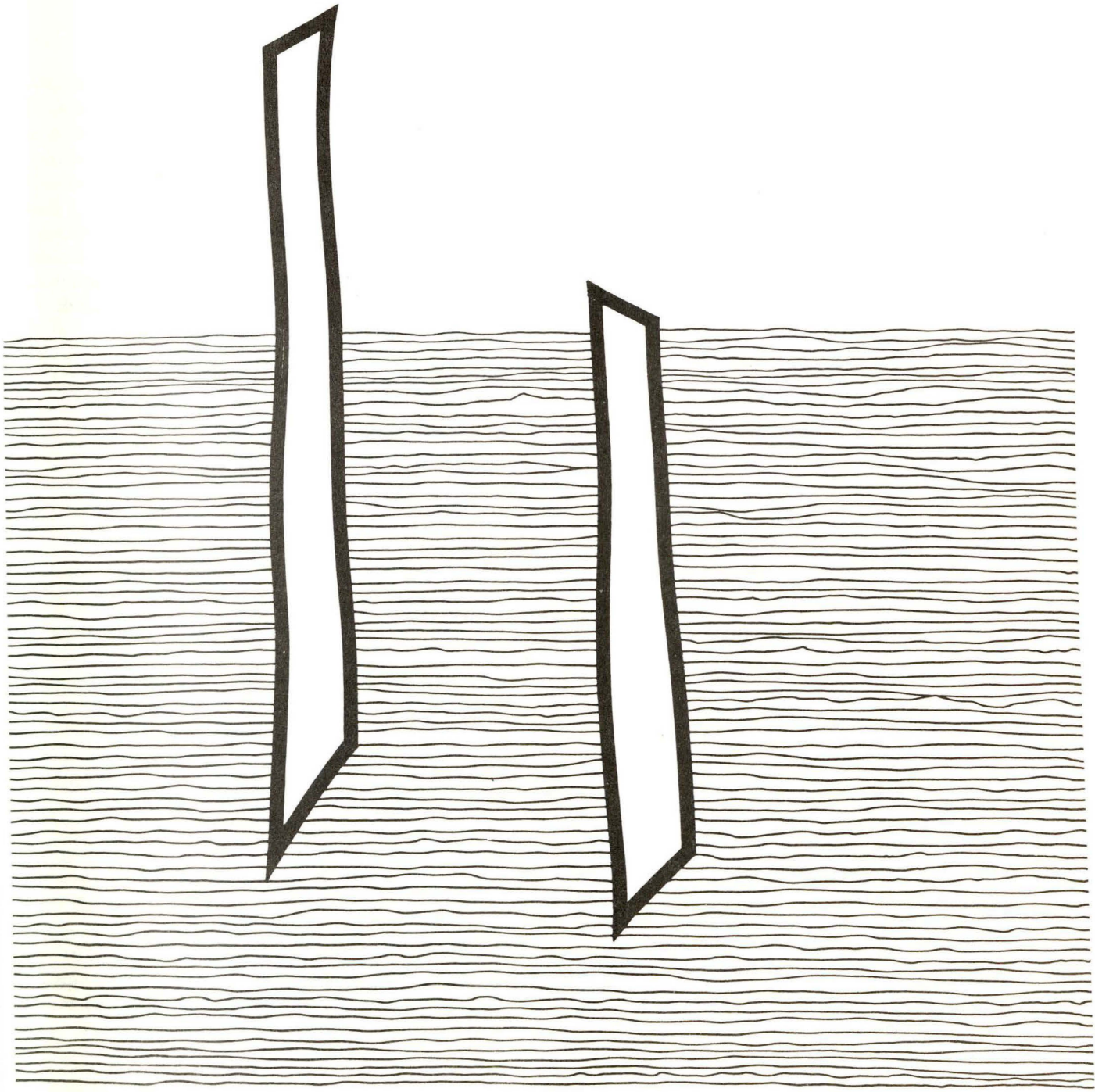
Forest
Service

North Central
Forest Experiment
Station

Research
Paper **NC-241**

Pre-plant Soaking of Dormant Populus Hardwood Cuttings

Howard M. Phipps, Edward A. Hansen, and Anne S. Fege



ACKNOWLEDGMENT

The authors wish to acknowledge the technical assistance of David Tolsted, Daniel Netzer, and William Danfield.

Contents

	Page
Effect of Soaking Duration	1
Effect of Soaking Depth	2
Water Uptake in Relation to Water Temperature	4
The Problem of Delays in Planting Soaked Cuttings	4
Soaking Effects as Related to Soil Moisture	5
Soaking in Relation to Planting Date	6
The Problem of Delayed Development of Cuttings Stored at Subfreezing Temperatures	7
Summary	8
Literature Cited	8

North Central Forest Experiment Station
Forest Service—U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota 55108
Manuscript approved for publication April 4, 1983
September 1983

PREPLANT SOAKING OF DORMANT *POPULUS* HARDWOOD CUTTINGS

Howard M. Phipps, *Research Forester,*
Edward A. Hansen, *Principal Hydrologist,*
Rhinelander, Wisconsin,
and **Anne S. Fege,** *Graduate Assistant,*
University of Minnesota,
St. Paul, Minnesota

Most *Populus* species and hybrids of the Aigeiros and Tacamahaca sections e.g., black poplars, cottonwoods, and balsam poplarsare readily propagated from dormant hardwood cuttings. Cuttings provide a convenient means of establishing fast growing, short rotation plantations for producing fiber or energy. As a standard procedure we harvest 1-year-old coppice shoots from a cutting orchard in December or January and cut them into 20 cm lengths. Cuttings with a diameter from 9 to 12 mm are selected and stored in sealed plastic bags at a temperature a few degrees below freezing. In the spring, cuttings are planted about 15 cm deep. However, early survival and growth of such plantations will depend largely on cutting vigor and weather conditions at planting time. One treatment that has been shown to increase early cutting survival and growth—especially during hot, dry periods—is to soak the cuttings before planting.

In a study with several *Populus* clones Bloomberg (1963) found that increased cutting moisture content significantly increased the number, length, and weight of initial roots of cuttings, and he also demonstrated the importance of these roots to subsequent survival and growth. Petersen and Phipps (1976) compared field survival of cuttings soaked in water with unsoaked cuttings of three different *Populus* clones and found soaking increased the rate of leaf flushing and survival of all clones. Similar benefits of water soaking to the field performance of *Populus* cuttings were found by dePhilippis (1966) in Italy and by Edwards and Kissock (1975) with both *Populus* and *Salix* clones in New Zealand.

To further evaluate water soaking and other preplanting treatments, we investigated such variables as water temperature, length of soaking time, depth of cutting immersion, and effects of soaking in relation to time of planting and soil moisture. This paper reports the results of a number of interrelated studies designed to improve our knowledge and develop techniques for preplant handling of hardwood cuttings. Use of these techniques should improve early survival and growth of new plantations.

EFFECT OF SOAKING DURATION

Several tests were performed in a growth room to determine how long cuttings must be soaked in water to gain the best subsequent root and shoot growth. As part of a study to determine the effects of moisture stress on hardwood cutting performance, we compared the effects of soaking for different lengths of time on the earliness of bud flush and the rate of shoot growth. We used 20-cm-long cuttings from the following clones: NC-9922, NC-5260, and NE-387 (NC-5262) (see table 1 for parentages). The cuttings were given the following treatments: (1) no pretreatment (cuttings were taken directly from cold storage at 2°C and planted); (2) cuttings were "warmed" at 3°C for 2 weeks and then soaked in the dark in water at 16°C for 4 days, and (3) cuttings were warmed and soaked as in treatment 2 except soaking duration was 10 days at which time the roots were about to emerge. In this study, as well as the studies described below, cuttings were soaked in the dark to avoid possible inhibition of root growth by light.

Two replications of all clone x soaking treatment combinations (54 cuttings total) were placed in a randomized block design in each of 12 boxes; each box having a different soil moisture tension ranging

Table 1.—*Clone numbers and parentage of* Populus *hybrids used in preplant treatment studies*

Clone no.		
Original Northeast	North Central	Percentage
NE-386	NC-5263	*Populus* cv. *Candicans* X (*P.* X *berolinensis*)
NE-387	NC-5262	*Populus* cv. *Candicans* X (*P.* X *berolinensis*)
NE-252	NC-5334	*Populus deltoides* var. *angulata* X *P. trichocarpa*
—	NC-5377	*Populus* X *euramericana* cv. Wisconsin #5
—	NC-9922	*Populus* spp. (Very similar to NE-252)
—	NC-5260	*Populus tristis* X *P. balsamifera* cv. Tristis #1

from 0 to -0.6 bars. The cuttings were all planted on the same day. Shoot length was measured at 10, 14, and 18 days after planting. For analyzing the effects of the soaking period duration, all soil moisture treatments were pooled.

The soaking treatments had a major effect ($p = 0.05$) on the rapidity of flushing and consequently on shoot length (fig. 1). In almost all cases, the no-soaking treatment was the poorest and the 10-day soak the best in terms of percent flushing and shoot length at either 10 or 18 days. At the 10-day measurement, from 45 to 98 percent of the cuttings in the 10-day soaking treatment had flushed depending upon clone; the 4-day soak was intermediate; and none of the unsoaked cuttings had flushed. By 18 days the percentage of flushed cuttings of the 4-day soak was almost equal to that of the 10-day soak. However, the shoot length of the flushed 4-day soaked cuttings was still much less than that of the 10-day soak. Shoot length increased with soaking duration because of earlier flushing. Once the cuttings flushed, growth rate was similar as evidenced by the nearly constant difference in shoot length between the 4- and 10-day soaking treatments measured at 10 days and 18 days.

Evidence of the importance of soaking was also obtained in another growth room test in which response was measured in terms of average shoot length, number of roots, length of longest root, and total root dry weight. In all cases, cuttings that were not soaked showed the least growth of both roots and shoots. For those treatments that involved soaking, results differed to a large extent by clone. For example, 14 days after planting, root length and root dry weight of clone NE-252 (NC-5334) increased significantly with increased soaking duration up to 11 days (the point of root emergence). However, only root length

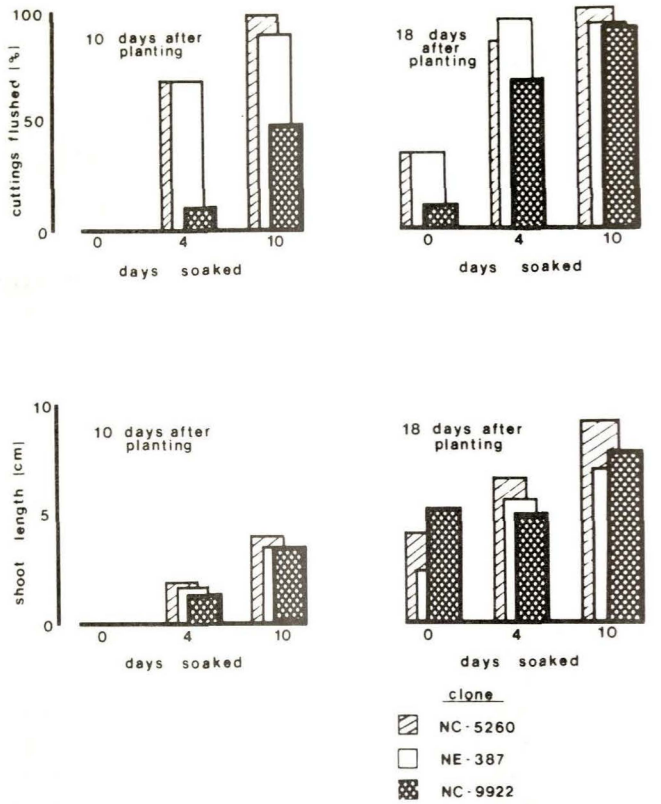


Figure 1.—*Relation of early bud flushing and shoot length to soaking pretreatments at 10 and 18 days after planting. Data from soil moisture tension treatments were pooled for each soaking treatment.*

of clone NC-5377 increased significantly during the same period. Although average shoot length of both clones increased with soaking duration, statistical significance could not be shown.

On the average, soaking cuttings to the point of root emergence (from 9 to 11 days in 16°C water) was most effective for stimulating root and shoot development. Significant response differences to soaking duration due to clone have also been reported by other investigators (dePhilippis 1966; Edwards and Kissock 1975). Because the optimum soaking duration may differ by clone, soaking to the point of root emergence would be the most practical method when dealing with unfamiliar clones (fig. 2).

EFFECTS OF SOAKING DEPTH

How deeply cuttings must be immersed in water or whether immersion is actually necessary to obtain maximum water uptake and to stimulate rooting was investigated in two studies. In the first study,

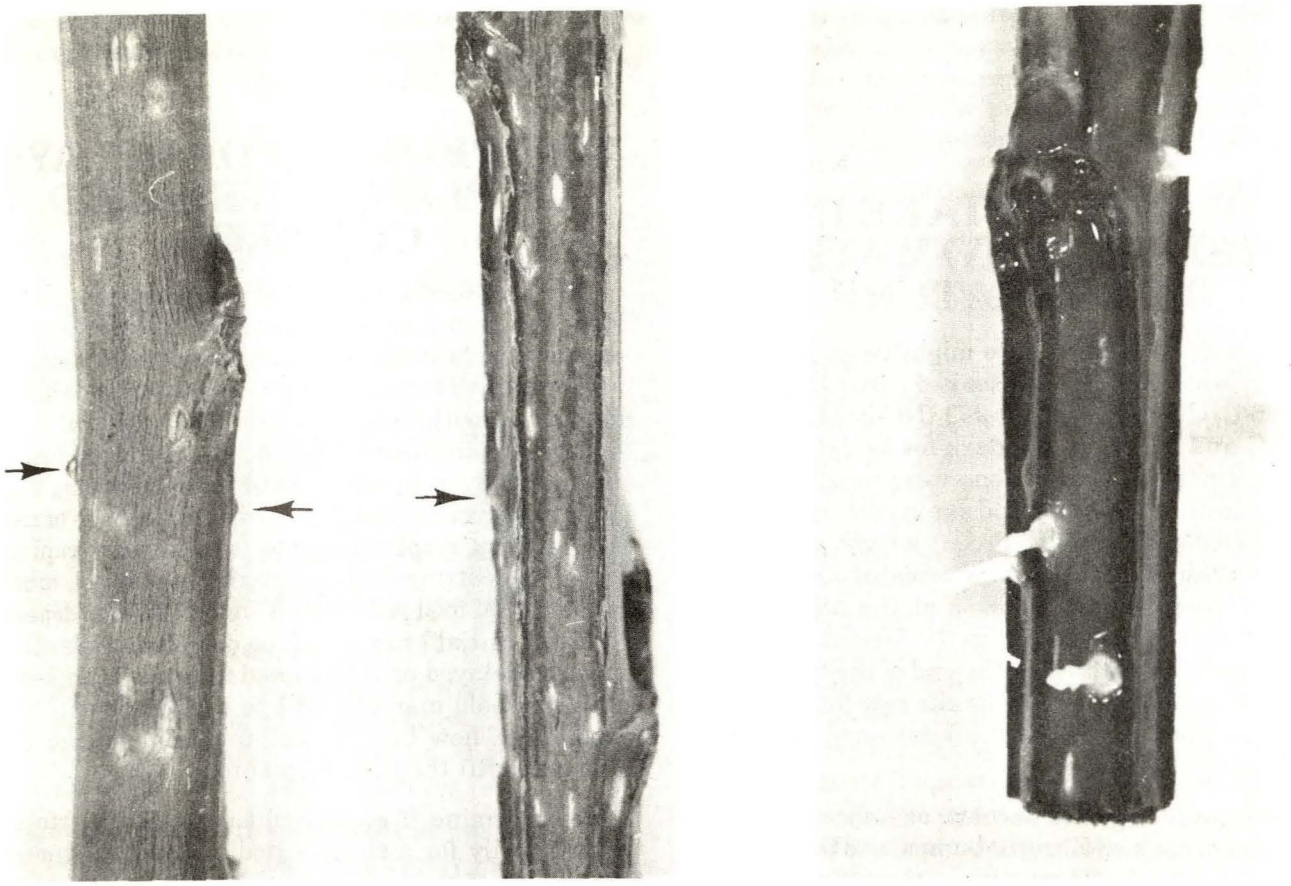


Figure 2.—Populus *hardwood cuttings soaked to the proper stage for planting (left and center) with swellings of roots about to emerge as indicated by the arrows. On the right a cutting soaked too long with roots already emerged.*

20-cm-long cuttings of clone NC-9922 were treated as follows: (1) entire cuttings exposed to a moisture-saturated atmosphere in a sealed plastic bag; (2) bases soaked to 3 cm depth in a saturated atmosphere; (3) bases soaked to 15 cm depth; and (4) bases soaked to 15 cm depth in aerated water. The last two treatments were applied in open containers and therefore not in a saturated atmosphere. Responses measured were number of days until roots emerged and weight gain at the time of root emergence. No significant differences were found in percent weight gain due to treatment (shown below) except for the cuttings in the saturated atmosphere treatment which absorbed significantly less ($p = 0.05$) water. Percent weight gain was used because within any treatment weight gain was proportional to initial cutting weight (size). Roots emerged at about 15 days in all treatments except the aerated 15 cm soak treatment where rooting began after about 24 days.

Treatment	Percent weight gain
1. Moist atmosphere	10
2. 3 cm soak	19
3. 15 cm soak	19
4. 15 cm soak with aeration	29

In a second test, 20-cm-long cuttings of clones NE-252 (NC-5334), NE-387 (NC-5262), and NC-5377 were soaked to depths of 3 cm and 15 cm for 9 days to determine effects on shoot length, root length (as measured by the two longest roots per cutting), and total dry weight of roots. Results showed no effect of soaking depth on shoot length. Root length and root dry weight were greater for the deeper soaking treatment (5 percent and 24 percent, respectively), but statistical significance ($p = 0.05$) was found for only one clone, NC-5377.

These tests show that soaking of 20-cm-long cuttings in 15 cm of water may slightly benefit root growth of certain clones compared to a shallow soaking of 3 cm. With other clones no benefit to growth

was indicated by the deeper soaking treatment. Although some uptake will occur by merely exposing the cuttings to a moisture-saturated atmosphere, significantly more moisture will be absorbed when the bases of the cuttings are immersed.

WATER UPTAKE IN RELATION TO WATER TEMPERATURE

To find out if temperature might be an important factor in water uptake, we soaked cuttings of clones NE-386 (NC-5263) and NE-252 (NC-5334) in water at 4.4°C and 15.6°C in the dark for 14 days. Ten, 20 cm long cuttings of each clone were weighed before soaking in 15 cm of water and again each subsequent day to calculate average percent weight gains. The curves representing these gains revealed a more rapid and sustained weight increase at the higher temperature for both clones (fig. 3). Weight was still increasing substantially at the end of the test for the 15.6°C treatment, whereas uptake rate for the 4.4°C treatment plateaued at about 9 days and increased only slightly thereafter.

Root initials began to develop, as indicated by the formation of bark swelling or bumps, and buds began to break in the 15.6°C treatment about 8 days after soaking started. Even after 14 days no evidence of the initiation of growth was seen in the 4.4°C treatment.

These results suggest that a soaking temperature of 15.6°C would be superior to 4.4°C for several reasons. The higher moisture content may favor the production of a more vigorous initial root system, and initiation of root and shoot growth are accelerated thus reducing the soaking duration. Extended

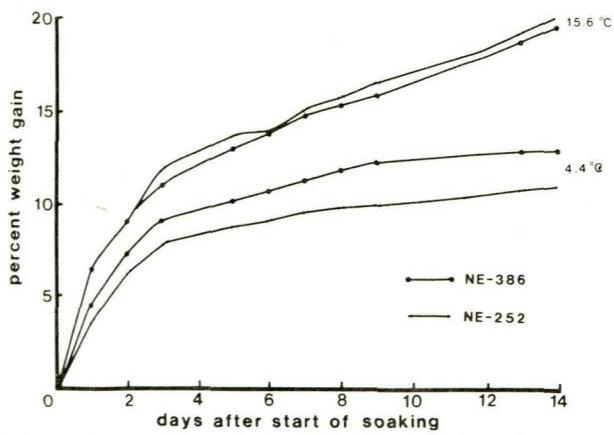


Figure 3.—*Percent weight gain of hardwood cuttings of two* Populus *clones in response to two water soaking temperatures.*

periods of soaking, especially if the water should stagnate, can be detrimental to subsequent growth (Edwards and Kissock 1975).

THE PROBLEM OF DELAYS IN PLANTING SOAKED CUTTINGS

When soaked cuttings have reached the proper stage for planting, as indicated by visible swelling of root initials and leaf buds, roots and shoots extend very rapidly. Therefore, cuttings at this stage should be planted within a day or two so that initial roots and developing leaves will not be damaged either mechanically or by exposure to heat and drying during transport and planting. Also, at this stage of root development respiration rates will increase rapidly and if the cuttings are not promptly planted, much of the stored food reserves on which cuttings depend for their initial growth will be depleted. If planting must be delayed or interrupted for more than a few days, the field manager will be confronted with the problem of how best to maintain the vigor of the cuttings until they can be planted.

To determine if soaked cuttings could be stored satisfactorily for a short period of time, we studied the effects of storing hardwood cuttings (soaked to the point of root emergence) of clones NE-386 (NC-5263) and NE-252 (NC-5334) in crushed ice in styrofoam boxes for 2 weeks. The effects of air drying soaked cuttings for 8 hours at about 24°C were also studied, with and without subsequent 2 week storage on ice before planting. The drying treatment was chosen to simulate a harsh condition that might occur during a field planting operation. These treatments were superimposed on cuttings soaked for various lengths of time in water at 4.4°C and 16°C. After treatment, cuttings were potted, grown for 4 weeks in a growth room, and responses measured in terms of number of shoots and length of the longest shoot and longest root.

Neither shoot number nor shoot length of either clone was significantly reduced by either cold storage or drying alone. However, drying followed by cold storage reduced average root length by approximately 15 mm (fig. 4). Other significant differences found in this study were: clonal differences in the number of shootsgrowth of clone NE-386 (NC-5263) was consistently greater than that of clone NE-252 (NC-5334)and growth of shoots and roots was greater for the 16°C soaking temperature. These results indicate that exposing soaked cuttings to both drying and cold storage may cause a slight, early loss of root

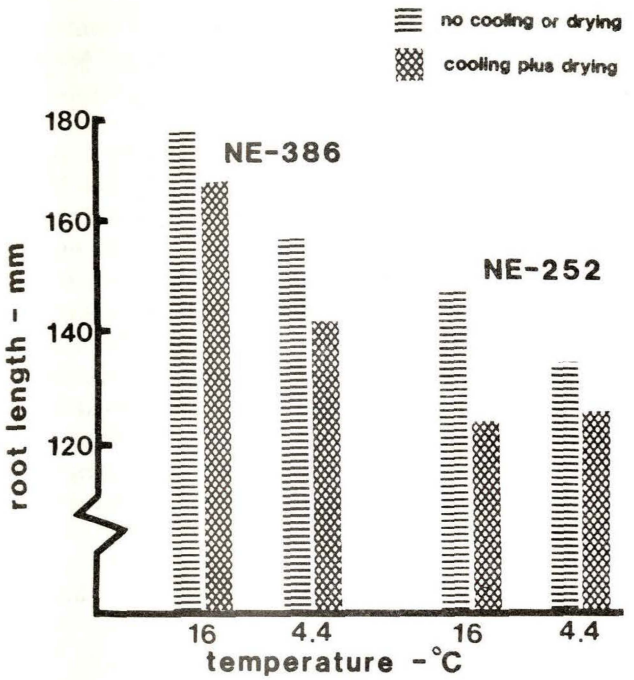


Figure 4.—*Effect of cooling plus drying treatments on root length of two Populus clones 4 weeks after planting. Cuttings were soaked at either 16°C or 4.4°C for 10 days before planting.*

growth. Whether the effects of this loss would persist after field planting and significantly reduce biomass is not known. However, in view of the otherwise normal survival and top growth development it is likely that adverse effects would be negligible for short periods of drying and up to 2 weeks storing on ice. Thus, it appears that up to 8 hours drying can be tolerated (though it should be avoided if at all possible) and that storing soaked cuttings on ice for as long as 2 weeks will maintain the vigor of soaked cuttings when unavoidable planting delays or interruptions are experienced.

SOAKING EFFECTS AS RELATED TO SOIL MOISTURE

The advantages of soaking *Populus* hardwood cuttings were observed in a field planting made during a year with an exceptionally hot, dry spring. Unsoaked cuttings showed very slow bud break and poor rooting in contrast to soaked cuttings, which developed and grew with normal vigor. Measurements of soil moisture tension during this period showed a range of -0.2 to -0.4 bars, which ordinarily indicates adequate moisture for satisfactory cutting development. We speculated that the hot, dry atmospheric conditions during the time of planting depleted cutting moisture reserves before their root systems could develop and replace the moisture loss.

To more closely define the relation between soil moisture status and rate of flushing and shoot growth, we studied the effects of various soil moisture tensions on the development of soaked cuttings.

Part of the methodology for this study has been described in the section on "Effect of Soaking Duration". Additional details are as follows. Twelve boxes were lined with aluminum foil and plastic to prevent moisture or gas movement through the sides or bottom of the boxes. Soil at different moisture tensions (achieved by mixing different quantities of water with each soil batch) was then placed in the boxes and covered with polyethylene to prevent moisture loss but yet permit gas exchange. The goal was to have the soil moisture tensions equally distributed between 0 and -0.6 bars. Soil moisture tension was monitored with a soil moisture block in the two driest treatments and with a tensiometer centrally located in each box in the other treatments. Growth room conditions were 15 hours of daylight, day-night temperatures of 27°C and 16°C, respectively, and soil temperature fluctuating diurnally between 30°C and 20°C. Although we used three clones in this study, the experimental results were similar for all clones and therefore we will present the data for only one clone (NC-5260).

The soaking treatments accelerated bud flushing over the entire range of soil moisture tensions investigated. The advantage of soaking on flushing is particularly evident at the drier (-0.5 bar) soil moisture tension where none of the unsoaked cuttings but all of the 10-day soaked cuttings had flushed 18 days after planting (table 2). Also, almost all of the 10-day soaked cuttings had flushed by just 10 days after planting. In contrast, none of the unsoaked cuttings flushed by 10 days after planting.

The accelerated flushing from soaking resulted in increased shoot length at all soil moisture tensions (fig. 5). Shoot length measured 10 days after planting averaged about 2 cm longer (about twice as long) for 10-day as compared to 4-day soaked cuttings. This

Table 2.—*Effect of soaking cuttings on percent flushing over a range of soil moisture tensions*

(In percent flushed)

Soaking treatment	10-day results tension (– bars)			18-day results tension (– bars)		
	0.1	0.3	0.5	0.1	0.3	0.5
Unsoaked	0	0	0	66	17	0
4-day	92	58	25	100	92	58
10-day	100	100	92	100	100	100

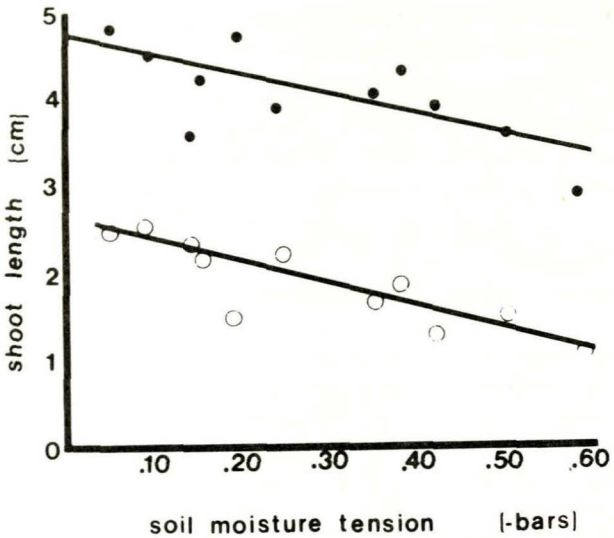


Figure 5.—*Relation of shoot length at 10 days to soil moisture tension for soaking treatments of clone NC-5260. The treatments consisted of soaking 10 days (•), and 4 days (○). The unsoaked cuttings had not yet flushed.*

increase in shoot length was constant for the range of soil moisture tensions examined. The regressions of shoot length against soil moisture tension were linear and significant. The effects of the soaking treatments were significantly different from each other and from the unsoaked treatment.

Thus, soaking accelerated flushing which in turn increased early growth under all soil moisture conditions. Perhaps most importantly, soaking may make the difference between success or failure of the cuttings under drier (-0.5 bar) soil moisture conditions.

SOAKING IN RELATION TO PLANTING DATE

Because it is possible that soaking may be more effective at certain times during the planting season than at others, we studied the effects of soaking on survival and height growth of cuttings planted at various dates during the season. Soaked and unsoaked cuttings of clones NC-5260 and NC-9922 were planted every 2 weeks beginning just after snowmelt and continuing throughout the summer. Half the cuttings of each clone were soaked at a 15 cm depth for 5 days prior to planting. Five cuttings of each treatment were planted at randomly selected locations in each of eight replications of which four were irrigated and four unirrigated. Tree height and survival were measured at the end of the first growing season.

Due to the wet season and good weed control, irrigation had no significant effect on survival or height growth so we pooled the data from the irrigated and unirrigated plots for analysis of soaking effects. Soaking generally increased height growth regardless of the planting date (fig. 6). Only the May 7 planting date showed no soaking benefit and the late August planting dates showed mixed benefits by clone from soaking. Because height growth did not differ significantly with planting date during the first four planting dates, those dates were pooled for analysis of variance to determine soaking effects. The results showed that soaking significantly increased height growth of both clones by 9.8 cm (about 13 percent). Mean tree heights for the first four planting dates of both clones pooled along with their standard errors are shown below.

Treatment	Tree height (cm)	Standard error
Soaked	86.22	1.26
Unsoaked	76.47	1.25

Soaking also resulted in increased height growth for the June 18 and the July 16 planting dates. Later dates showed mixed benefits from soaking. Soaked cuttings planted at those later dates were more susceptible to damage from late summer frosts than unsoaked cuttings. In general, the growth lost from freeze-back was about the same as the growth gained from soaking.

In conclusion, it appears that soaking cuttings increases tree height throughout the normal spring-early summer planting period. Because these results were obtained under wet field conditions, soaking benefits could be even more pronounced during dry conditions.

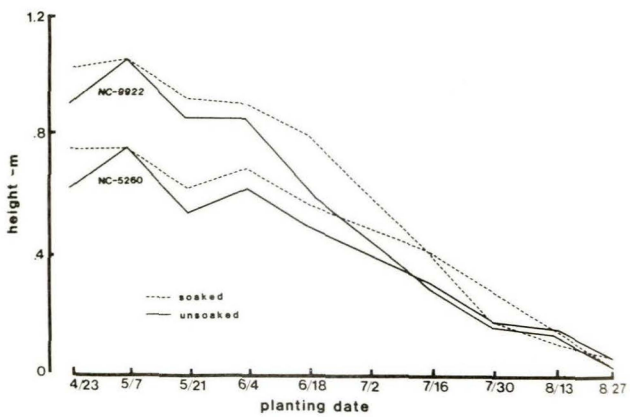


Figure 6.—*Effect of soaking cuttings on first season height growth as related to planting date for two clones.*

THE PROBLEM OF DELAYED DEVELOPMENT OF CUTTINGS STORED AT SUBFREEZING TEMPERATURES

Populus hardwood cuttings usually store well for 2 to 3 months at a temperature of about 3°C. For longer periods, it is advisable to store them at subfreezing temperatures to prevent premature sprouting and deterioration. However, storing cuttings at -17.8°C or -3.9°C for 5 months significantly delayed both shoot and root development compared to storing at 3°C (Phipps and Netzer 1981). Although the cause of this phenomenon is not known, it is probably associated with the activity of enzymes and hormones necessary to resume growth and mobilize food reserves. Because field establishment success will largely depend on how rapidly root systems develop, it was important to find a solution to the problem of delayed root and shoot development. Therefore, we investigated the possibility of overcoming this growth inhibition by transferring cuttings that had been in subfreezing storage to a temperature of 3°C ("warming") for various periods of time before soaking. Variables also studied in this series of tests were length of the soaking period and depth of soaking as covered in previous sections. In a preliminary test, cuttings of four clones were "warmed" for 0, 2, or 4 weeks and then soaked in 15 cm of water for either 0, 1, or 3 days, or until roots began to emerge. Cuttings were then potted and grown for 3 weeks in a growth room. Growth responses measured were: average shoot length, average number of roots, and average length of the three longest roots per cutting. Most of the cuttings that were neither "warmed" nor soaked failed to develop shoots or roots by the end of the test, so this treatment was eliminated from further testing. Although soaking was partially effective in overcoming the inhibitory effects of storage, "warming" for 2 weeks before soaking was clearly the most favorable treatment (table 3). "Warming" for 4 weeks showed no additional benefit over "warming" for 2 weeks.

Table 3.—*Effects of "warming" cuttings before soaking on root development. Data are averages of 1 day, 3 day, and "to root emergence" soaking treatments as measured 3 weeks after planting*

"Warming" (wks)	Shoot length	Roots	Root length
	Cm	*No.*	*Cm*
0	18	16	12
2	24	19	16

To further define the most favorable "warming" procedure, we selected 20-cm-long cuttings of clones NE-387 (NC-5262), NE-252 (NC-5334), and NC-5377 that had been stored for 1 year at -7°C and transferred them to a storage temperature of 3°C for either 1 or 2 weeks. Then we soaked the cuttings in either 3 cm or 15 cm of water for 3, 7, or 11 days at 16°C. After soaking, cuttings were planted 15 cm deep in boxes filled with sand and placed in a growth room with an 18 hour photoperiod and 25°/18°C day-night temperatures. Cuttings were watered daily and given a complete nutrient solution weekly. Growth responses measured 14 days after planting were: length of longest shoot, number of roots, and total weight of roots.

"Warming" for 2 weeks generally produced a greater number and weight of roots and longer shoots than did "warming" for 1 week (table 4). Survival was complete in all treatments. Because of the incomplete factorial design of the study, not all 3 and 11 day soaking and warming treatment combinations were included. Therefore, the 7 day soaking treatment was selected to best illustrate the differences between the two warming treatments. To compare specific treatments we analyzed treatment combinations that made up a complete factorial. For example, length of warming period was analyzed by comparing three pairs of treatments with the same length and depth of soaking and either 1 or 2 weeks of warming. This analysis showed that length of warming significantly affected all measurements ($p = 0.01$) with clone x length of warming treatment interaction significant for number of roots ($p = 0.05$). The effects of soaking depth were consistent with the effects described in the previous section "Effect of Soaking Depth".

Table 4.—*Growth response of three hybrid poplar clones stored at −7°C for 1 year, "warmed" for 1 or 2 weeks at 3°C, soaked for 7 days in 15 cm of water, and then grown for 2 weeks in a growth room*

	Clone					
	NE-387 (NC-5262)		NE-252 (NC-5334)		NC-5377	
Growth measurement	warmed		warmed		warmed	
	1 wk	2 wk	1 wk	2 wk	1 wk	2 wk
Roots (no.)	22	26	33	33	21	25
Roots weight (mg)	0.07	0.10	0.18	0.22	0.10	0.13
Longest shoot length (mm)	79	111	83	95	71	71

The differences between the treatment effects were not large for some clones and variables. However, it is likely that most of these warming and soaking treatments will improve rooting of cuttings in the field. All of the treatments produced a mean of at least 15 roots per cutting and primary shoots of 6.0 cm within 2 weeks in a growth chamber. It appears that a "warming" period of about 2 weeks at 3°C followed by soaking to the point of root emergence will bring cuttings that have been stored at subfreezing temperatures to the proper physiological condition for good postplanting development.

SUMMARY

To define soaking procedures that would most benefit cutting establishment and growth, we investigated the influence of such factors as length of soaking period, depth of soaking, and water temperature. We also studied the problem of maintaining soaked cuttings during planting delays and that of slow development of cuttings stored at subfreezing temperatures.

Although treatment effects in many studies were significantly influenced by clone, a soaking prescription was developed that is generally beneficial for all the clones in our studies. To overcome the problem of slow development of cuttings stored at subfreezing temperatures, "warming" by raising the storage temperature to 3°C for 1 or 2 weeks before soaking enables the cuttings to grow at a normal rate. Soaking in the dark to the point of root emergence in water at 16°C consistently accelerates growth. Some clones respond equally well to a soaking depth of either 3 cm or 15 cm, but other clones benefit more from the deeper soaking. Therefore, the latter treatment is recommended, especially for unfamiliar clones. Soaked cuttings ready for planting can be stored on ice for as long as 2 weeks with little loss of subsequent growth. Although root growth was reduced slightly, overall development of cuttings stored on ice was essentially equal to that of unstored cuttings. Air drying soaked cuttings for 8 hours also had negligible adverse effects.

In field studies we found that water soaking improves survival and growth of cuttings over a wide range of soil moisture conditions. In particular, water soaking is beneficial under hot, dry conditions that induce high moisture stress. Even under ideal weather and site conditions soaking may increase shoot growth. Soaking cuttings for 10 days in effect extends the field growing season by 10 days. This is the equivalent of a 10 percent extension of a 100 day field growing season; we measured a 13 percent first year growth gain for our approximate 90 day growing season even under irrigated field conditions. Benefits from soaking *Populus* hardwood cuttings may not always be realized to the same degree as found in studies described above because of the major influences exerted by local environmental conditions. However, at the least, soaking will help to ensure successful plantation establishment and growth under a variety of site and weather conditions.

LITERATURE CITED

Bloomberg, W. J. The significance of initial adventitious roots in poplar cuttings and the effect of certain factors on their development. For. Chron. 39(3): 279-289; 1963.

Edwards, W. R. N.; Kissock, W. J. Effect of soaking and deep planting on vegetative propagation of *Populus* and *Salix*. In: International Poplar Commission-15th Session; December 1975; FAO Rome; 1975. 13 p.

Petersen, L.; Phipps, H. Water soaking pretreatment improves rooting and early survival of hardwood cuttings of some *Populus* clones. Tree Planters' Notes 27(1): 12-22; 1976.

Philippis, A. de. Factors affecting the difficult rooting of cuttings in some poplars. Centro Di Sperimentazione Per La Pioppi-colture. C. P. 24–Casale Monferrato No. F. G. It. 122. E.N.C.C.–Rome; 1966.

Phipps, H.; Netzer, D. The influence of collection time and storage temperature on *Populus* hardwood cutting development. Tree Planters' Notes 32(4): 33-36; 1981.

Phipps, Howard M.; Hansen, Edward A.; Fege, Anne S. Preplant soaking of dormant *Populus* hardwood cuttings. Res. Pap. NC-241. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1983. 8 p.

Summarizes results of a series of growth room and field studies to develop and evaluate water soaking procedures for improving the establishment of *Populus* hybrid hardwood cuttings.

KEY WORDS: Vegetative propagation, hybrid poplar, plantation establishment, artificial regeneration

U.S. GOVERNMENT PRINTING OFFICE:1983-666-854/5060